Editorial

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Musings on more than 40 years in building performance simulation

The 40 years of BSER&T coincides with the revolution in building modelling and performance simulation that, although fuelled by the development and mass production of microprocessors, has been fashioned by the pioneering professionals who were able to forge connections between the worlds of building services engineering and software development. The career of Dru Crawley has not only witnessed this revolution but he has been instrumental in the creation and maturity of the open-access simulation environment that powers many of the research projects that are published in BSER&T. In this 40th year celebration issue Dru Crawley reflects on his career that personifies this revolutionary period.

From mainframe computers that filled rooms, an armful of input punched card decks, and 6 inch stack of continuous form 'green bar' paper for output to computers the size of a deck of playing cards . . . quite a ride over the last 40 years.

My road to building performance simulation started early in my college career. I was pursuing an undergraduate degree in architecture when my architecture technology professor, knowing my interest in computer analysis, handed me a computer tape and said, try to get this program to run on the university's IBM 360 mainframe computers. That tape contained the source code for NECAP (NASA's Energy Computer Analysis Program, a predecessor to CALERDA and what became DOE-1 and DOE-2). What did it take to create a simulation? My first step was to figure out the arcane JCL (Job Control Language) which instructed the mainframe what to do (compile, run the simulation). Then I created my (very simple) model. Every time I ran the simulation it had to compile the Fortran source code for NECAP and then run my deck. Usually it took a few hours, depending on the computer jobs in front of mine. In the days of punch cards, each line of Fortran code or input was a single card and input data had to be in the correct column or it would crash and not run. Together NECAP was about two boxes of punched cards (a card is 7–3/8 × 3–1/4 inches (18.7325 × 8.255 cm) and a box contained 2000 cards). Imagine your panic if you dropped the deck. Subsequently as an independent study course, I wrote an 'interactive interface' on the newer DEC 10, which didn't require punch cards. My professor gave my interface to one of his classes and they got extra credit if they got my interface to run a simulation. My interface automatically wrote the JCL which compiled the program (again) along with the NECAP input. Fortunately, the days of punched cards didn't last long. Many long nights trying to find that one card that had a misplaced comma . . .

I graduated with an architecture degree from Tennessee in the late 70s. I had already found that I was interested in energy efficiency and renewable energy. That led to work again using building energy simulation, first in a research group in Washington, DC, then a consultancy in Atlanta and London in the early 80s. At this point we had progressed beyond punched cards and now were using a mainframe computing service and DOE-2. This involved putting your phone headset in an acoustic coupler and dialling the mainframe. You could edit a file (slowly), tell the mainframe to run a simulation, print results, etc. One memory sticks out – checking to see if our simulation had run and seeing that it was waiting on the weather tape to mount. We were storing our working on large, 10.5 inch (26.7 cm) reels of tape stored in the computer services facility across the country. For the climate data, we depended on a separate weather tape and there were very few weather files available at that time (60 for all of the US). Lots of sending a 'mount weather tape' requests! Even then we were still printing the outputs and reviewing. An iterative and time-consuming process.

While I was in Atlanta, we had an opportunity you dream of in building simulation – to participate in a large new building project from predesign into construction. A corporate headquarters was being designed for a large multinational corporation outside Cleveland, Ohio. We were brought in at the beginning of predesign by the architect, one of their many consultants. Over the course of 18 months, we prepared studies of building shape, layout, systems, and efficiency measures through each phase of design. We even evaluated alternative chiller manufacturers during the bid process. In total, more than 125 energy simulations throughout design and construction. One of my favourite images is of my colleague standing, leaning on the 4 ft stack of DOE-2 simulation outputs just for this building project. A challenge was the evolving design from simple to complex over the design process. Our baseline for energy design changed as we learned about the cafeteria and computer centre that weren't documented in the early program materials. As even continues today, getting robust 3-D data from CAD then (and BIM today) was difficult. We dealt with the challenge of an evolving design as seen in these diagrams. We faced many of the same challenges when I worked in our London office, with the added challenge of the Atlantic in between members of our team. We provided building services design for a new corporate headquarters outside London including energy simulation. Again, we used the commercial mainframe service via acoustic coupler. But we had the advantage of time zones: the simulation team would complete their work and the simulations would be available the next morning for access in the UK.

About this time, a huge innovation was beginning to penetrate our offices – Personal Computers, initially the Apple II, then the IBM PC. Now we could have computing power at our desk but at a price and not everyone had one (yet). We had to wait a few years until our bound-to-mainframe simulation programs made it to those desktop computers.

By the middle of the 1980s, I had moved onto developing evaluating energy savings from commercial building energy standards at a national laboratory. Initially we were using the lab's local mainframe computer, again running DOE-2. Within a couple of years, desktop versions of DOE-2 became available and we were no longer tied to the expensive mainframe across campus or across the country. Over the course of six years we ran thousands of simulations of commercial buildings in support of national energy standards. Desktop computing became incredibly powerful quickly. Early in the 1990s, I moved to U.S. EPA and the early days of Energy Star Buildings – where I set up DOE-2 runs to support the evolving Energy Star commercial buildings program. I remember in 1994 excitedly telling a friend by email that we were able to move from a 386, to a 486 to a 586 (Pentium) over the course of several months. This cut the time for individual DOE-2 simulations from 18 minutes to under 3! While this was a huge difference, there was a huge backlog running on three desktops – more than 25,000 DOE-2 simulations were queued up. The PCs ran another two weeks after I left EPA.

When I moved to DOE in the early 90s, I became more of a producer than a user. I was initially responsible for DOE-2 and a few other tools. Early in my time there, an opportunity arose to merge the two major public tools – DOE-2 and BLAST – because the US Army was ending development and support of BLAST. Starting in 1996 with the core heat and mass balance engine within BLAST, we added daylighting and other important features in DOE-2 using what we called evolutionary re-engineering: pulling apart the hundreds of thousands of lines of spaghetti-like code, modularizing it, and bringing up to new Fortran standards. From this, EnergyPlus v 1.0 was released in April 2001. Simulation was becoming more important throughout this time – with LEED certification requiring simulation to achieve energy credits. This drove a new surge in simulation interest.

During that same time, I started work on a PhD in mechanical engineering, finally graduating in 2009 from the University of Strathclyde. My PhD thesis focused on using simulation as a policy tool – from standards setting and evaluating, utility incentives, and policy development. Essentially simulation was the core theme of my working career – the ability to estimate the impacts of proposed standards, value of technology change for utilities considering incentives, and for other policy development.

Throughout this period and continuing to today, building designers want to be able to reuse the wealth of 3-D geometry and other information promised by BIM. I wish I could say that getting data from BIM to building simulation was easy, but it still isn't. There are encouraging signs, as BIM developers are incorporating simulation into their products for, at least, early design evaluation. The benefits of reusing the 3-D model should encourage designers to try simulation.

I laugh today when I see all the excitement about cloud computing – we were using cloud computing with mainframe computers 40 years ago. Yes, there's radically more power available with multiple virtual machines and seemingly unlimited storage, and interfaces that make it easy to spawn hundreds of simulations and have the results in a short time. There's also amazing computing power that we carry with us every day – our phones. These mini computers have many times the power and storage capabilities than those mainframes of past days. I have seen major simulation tools compiled to run on a Raspberry, a computer the size of a deck of playing cards. (Yes, the keyboard, monitors, etc. are still large but the computer fits in your pocket.) Could you have imagined that you could have a 1 TB USB thumb drive for storage? They're already available for less than £20. While I haven't seen anyone port one of the simulation programs over to Android or iOS, I sure it will happen in time. More likely, we'll see interfaces that enable you to perform simulations in the cloud from your phone. All this power will enable our building simulations of the future – faster, intuitive, and helping us design the low-, zero-, and positive-carbon buildings of tomorrow. I can't wait to see where simulation can take us in the future!

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